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(54) **ROBOTIC CART CONFIGURED FOR EFFECTIVE NAVIGATION AND MULTI-ORIENTATION DOCKING**

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Publication Classification

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B65G 1/137 (2006.01)

(52) **U.S. Cl.**
CPC ***B65G 1/1375*** (2013.01)

(57) **ABSTRACT**

A system includes: a cart including: four legs; at least one shelf, each shelf attached to each of the legs; the cart having a generally rectangular shape, a width of the cart being longer than a length of the robot, a length of the cart being longer than a length of the robot; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles; and a robot comprising: a sensor; and a docking module, the docking module comprising retractable docking pins, each retractable docking pin configured, when extended upward, to mate with a corresponding docking receptacle, thereby securing the robot to a bottom shelf of the cart.

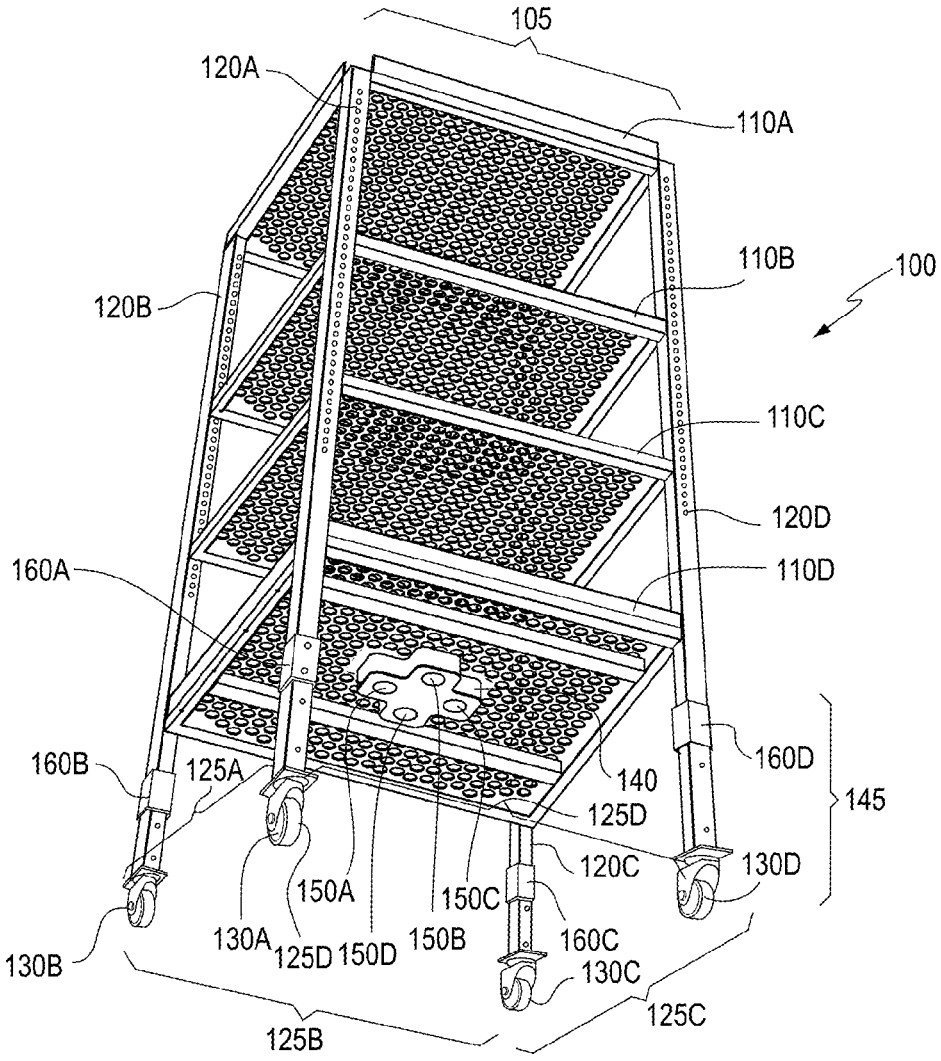

Fig. 1

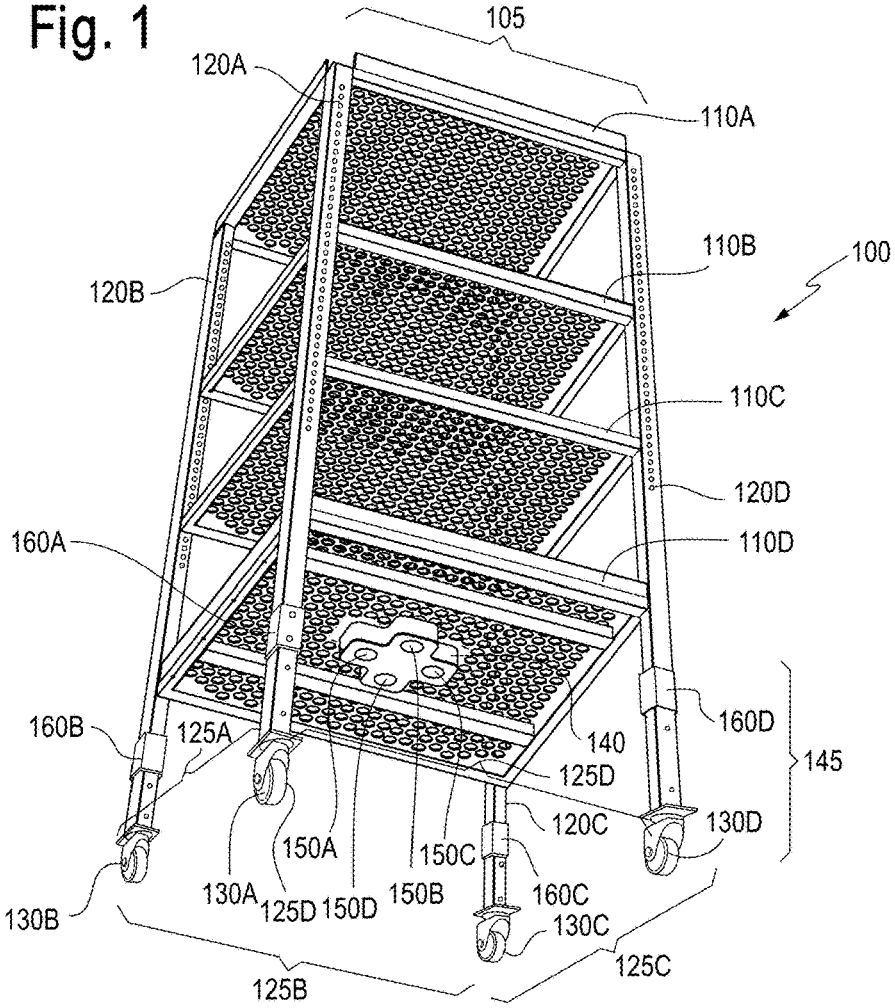
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Fig. 2

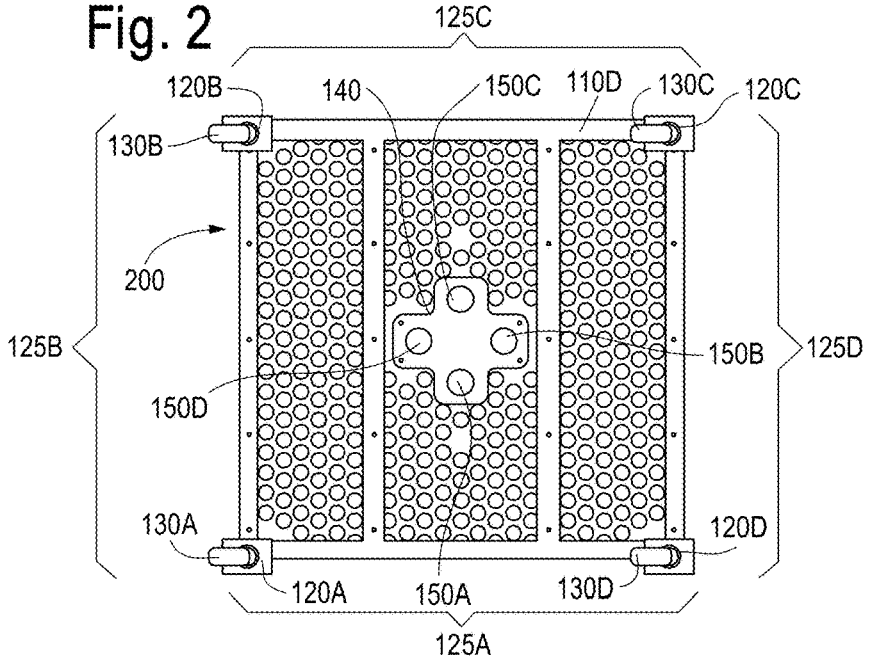
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Fig. 3

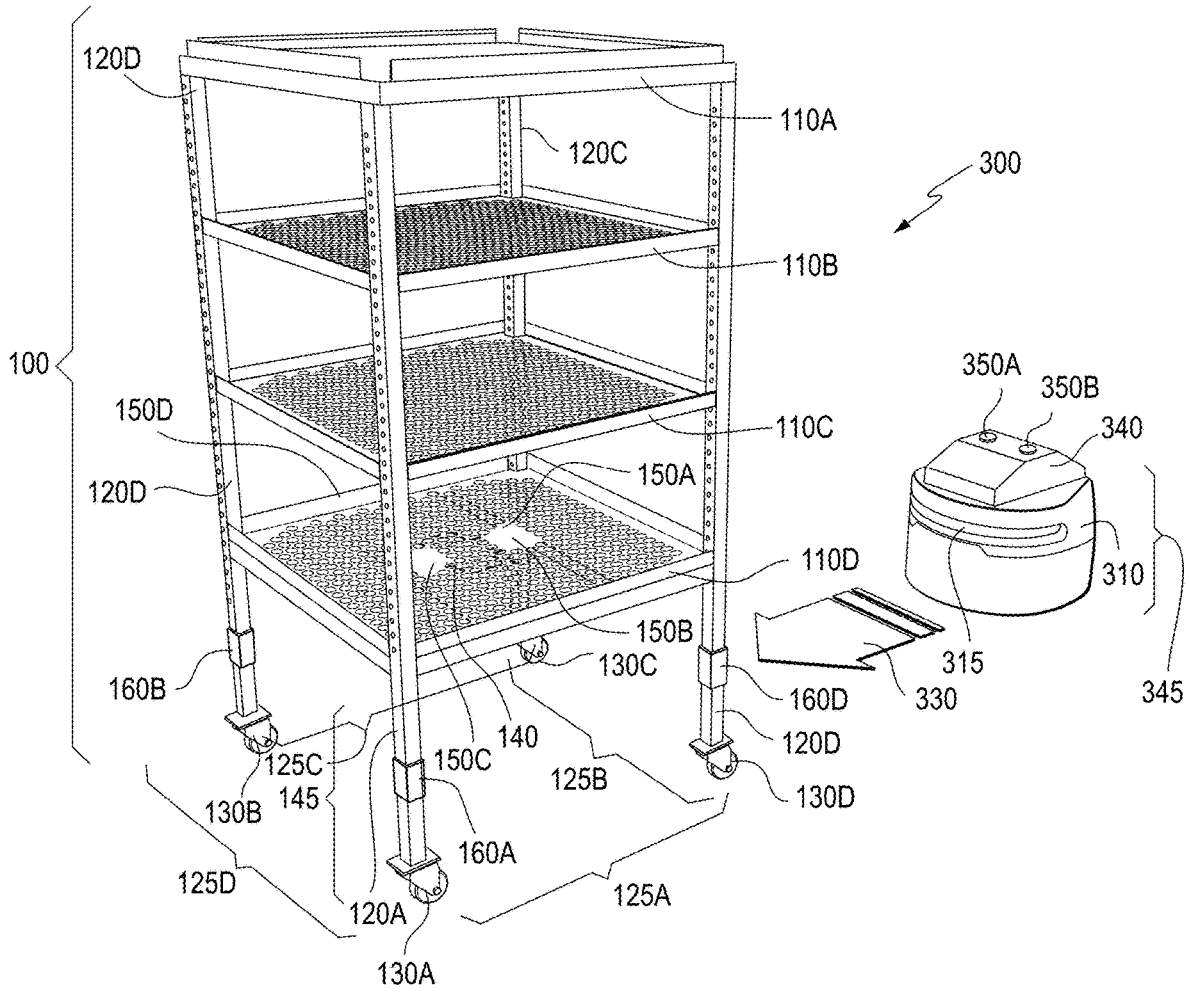
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Fig. 4A

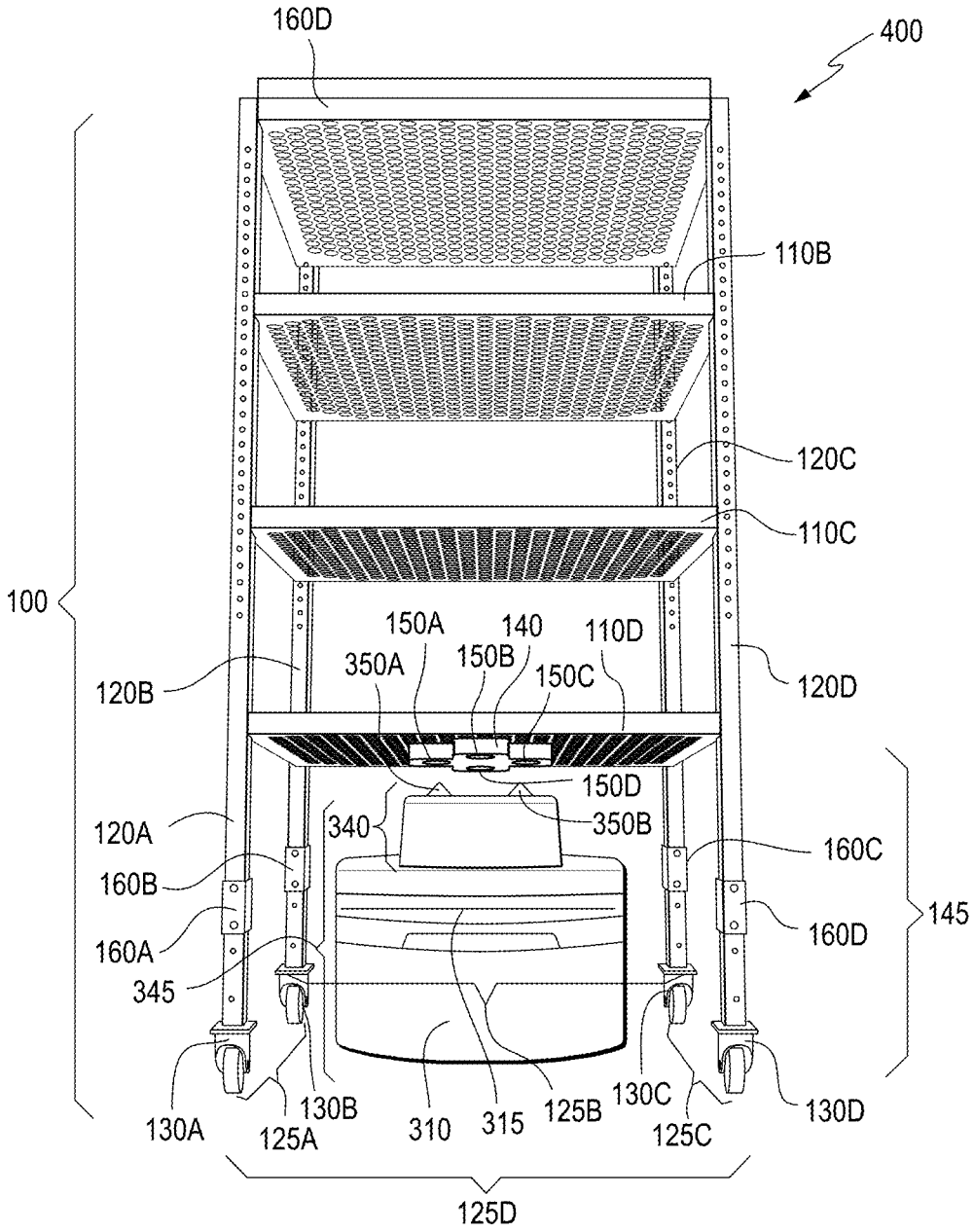
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Fig. 4B

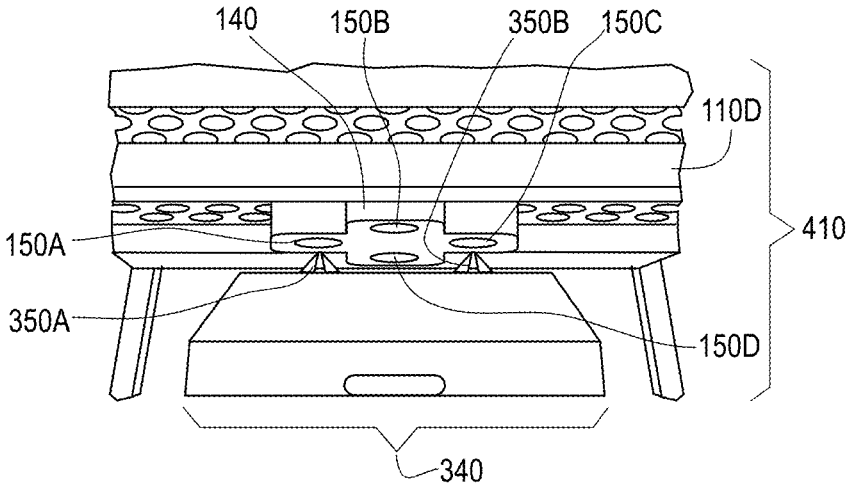
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Fig. 4C

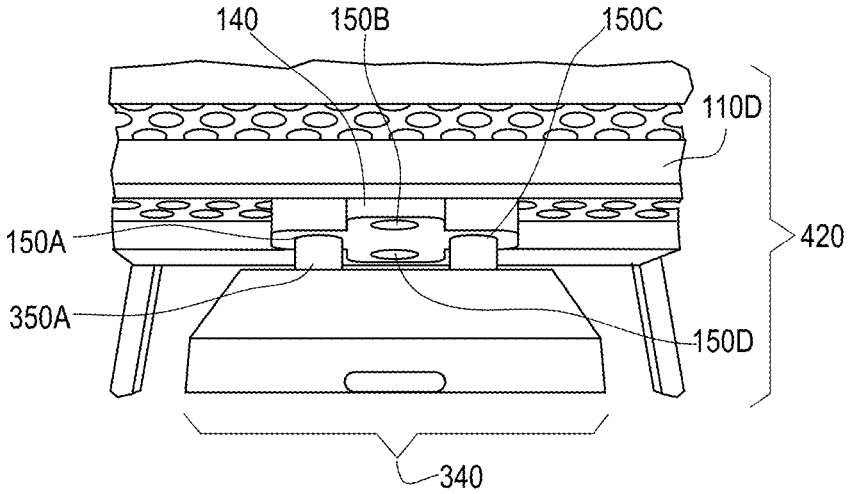
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Fig. 5A

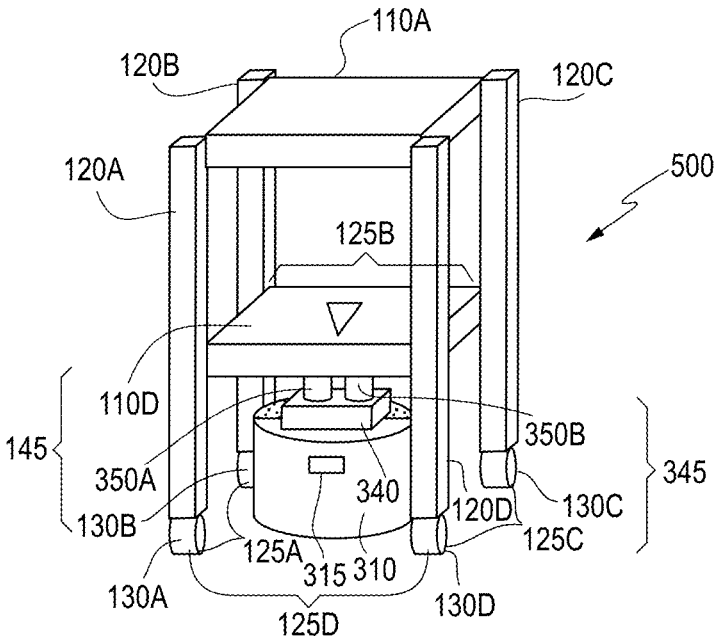
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Fig. 5B

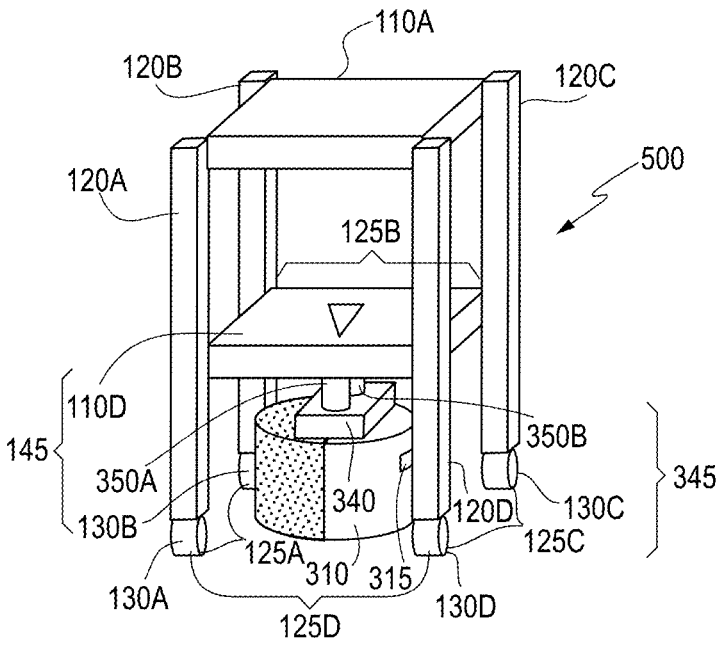
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Fig. 5C

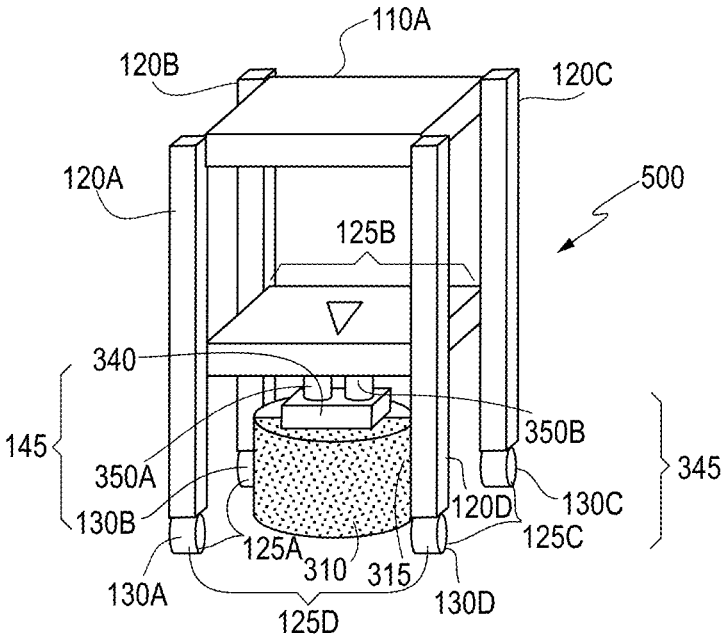
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Fig. 5D

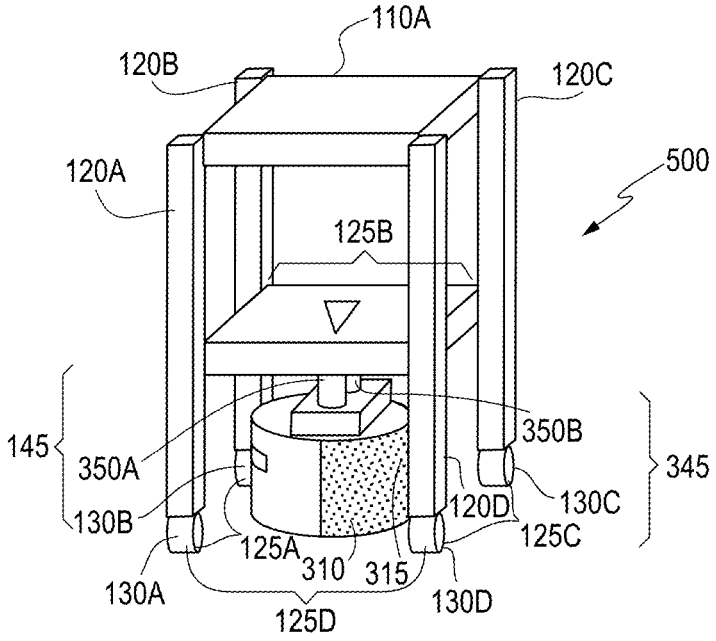
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Fig. 6A

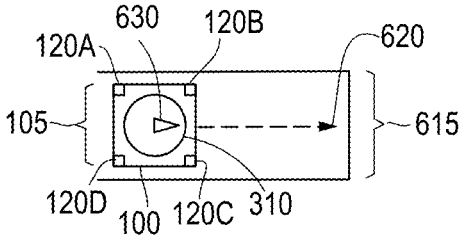

Fig. 6B

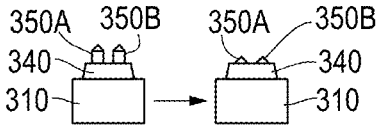

Fig. 6C

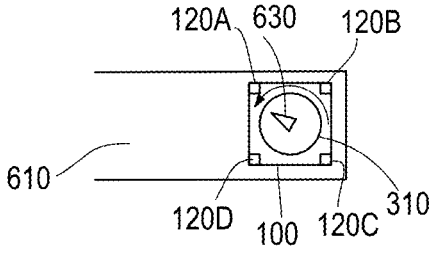

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Fig. 6D

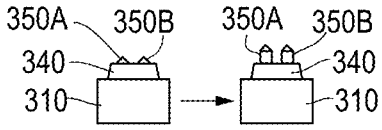


Fig. 6E

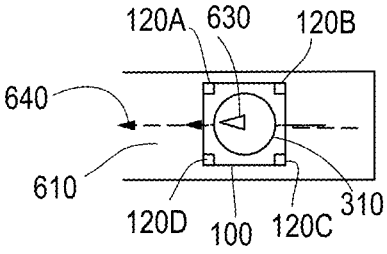


Fig. 7A

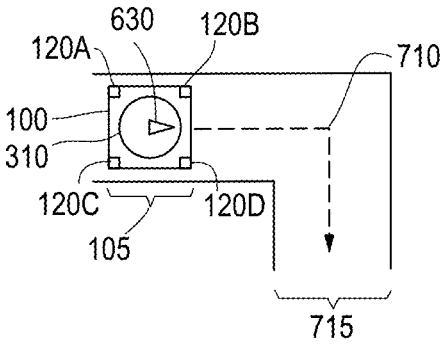
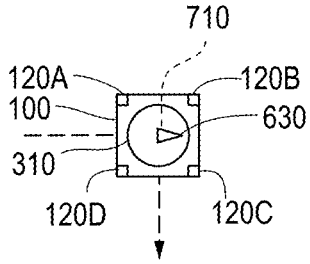


Fig. 7B



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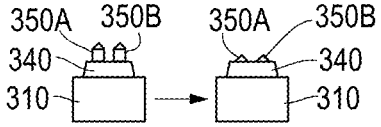

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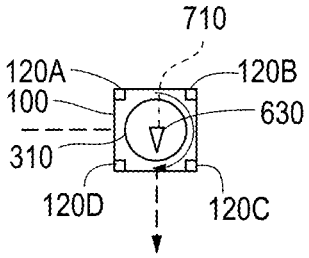
Fig. 7D



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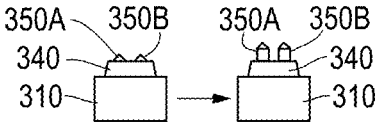


Fig. 7F

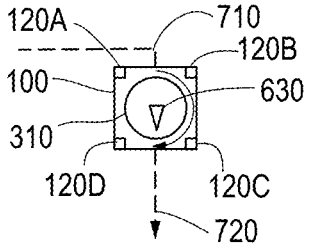


Fig. 8A

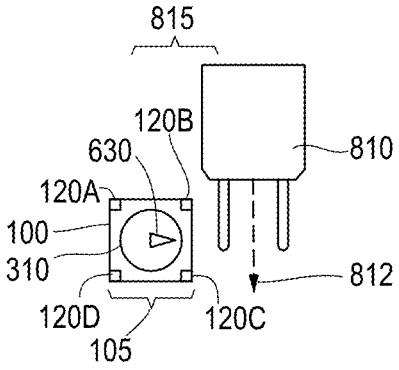
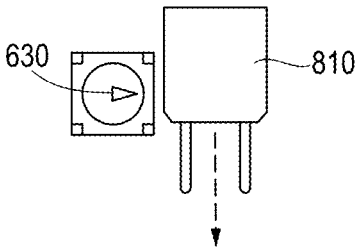


Fig. 8B



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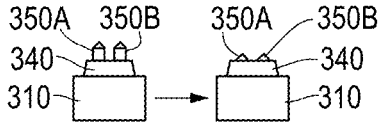

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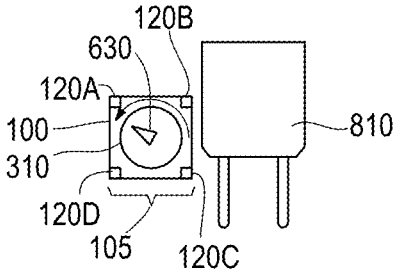
Fig. 8D



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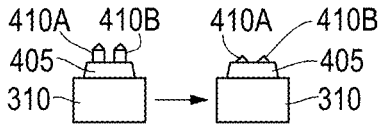

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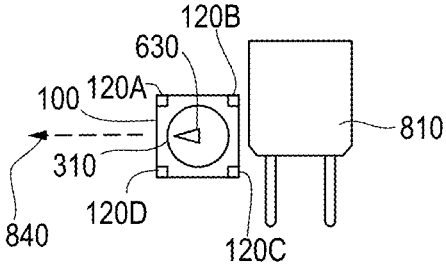

Fig. 9A

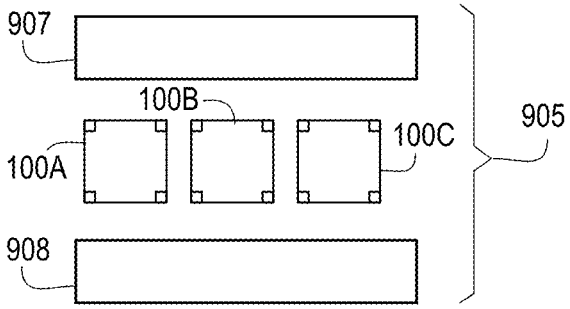

Fig. 9B

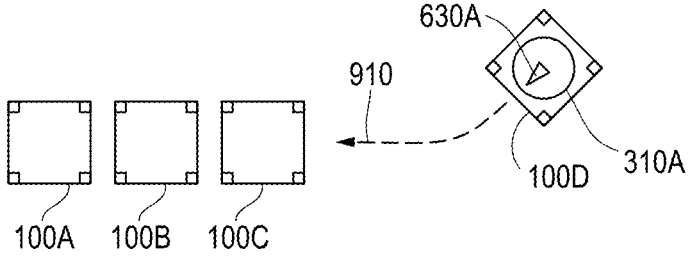

Fig. 9C

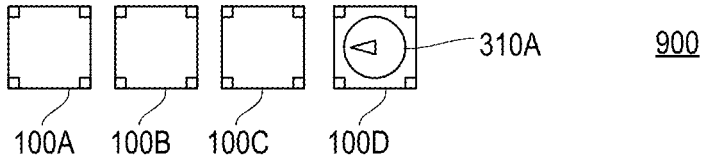

Fig. 9D

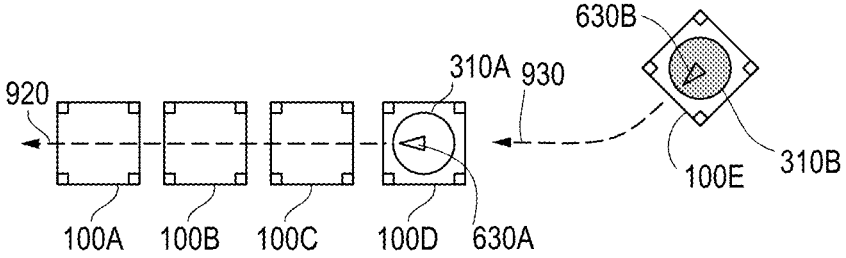

Fig. 9E

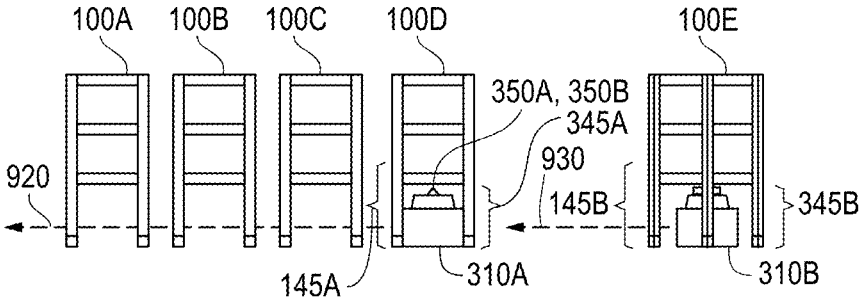

Fig. 9F

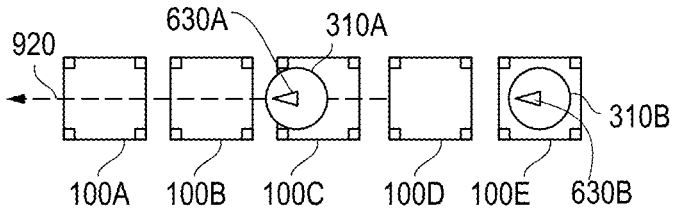
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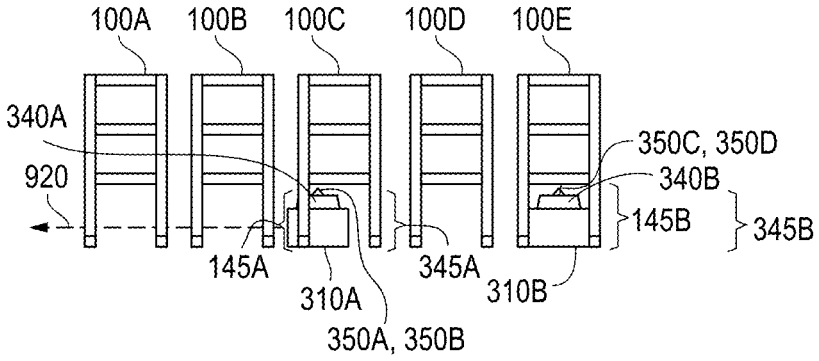
Fig. 9G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350A, 350B

Fig. 10

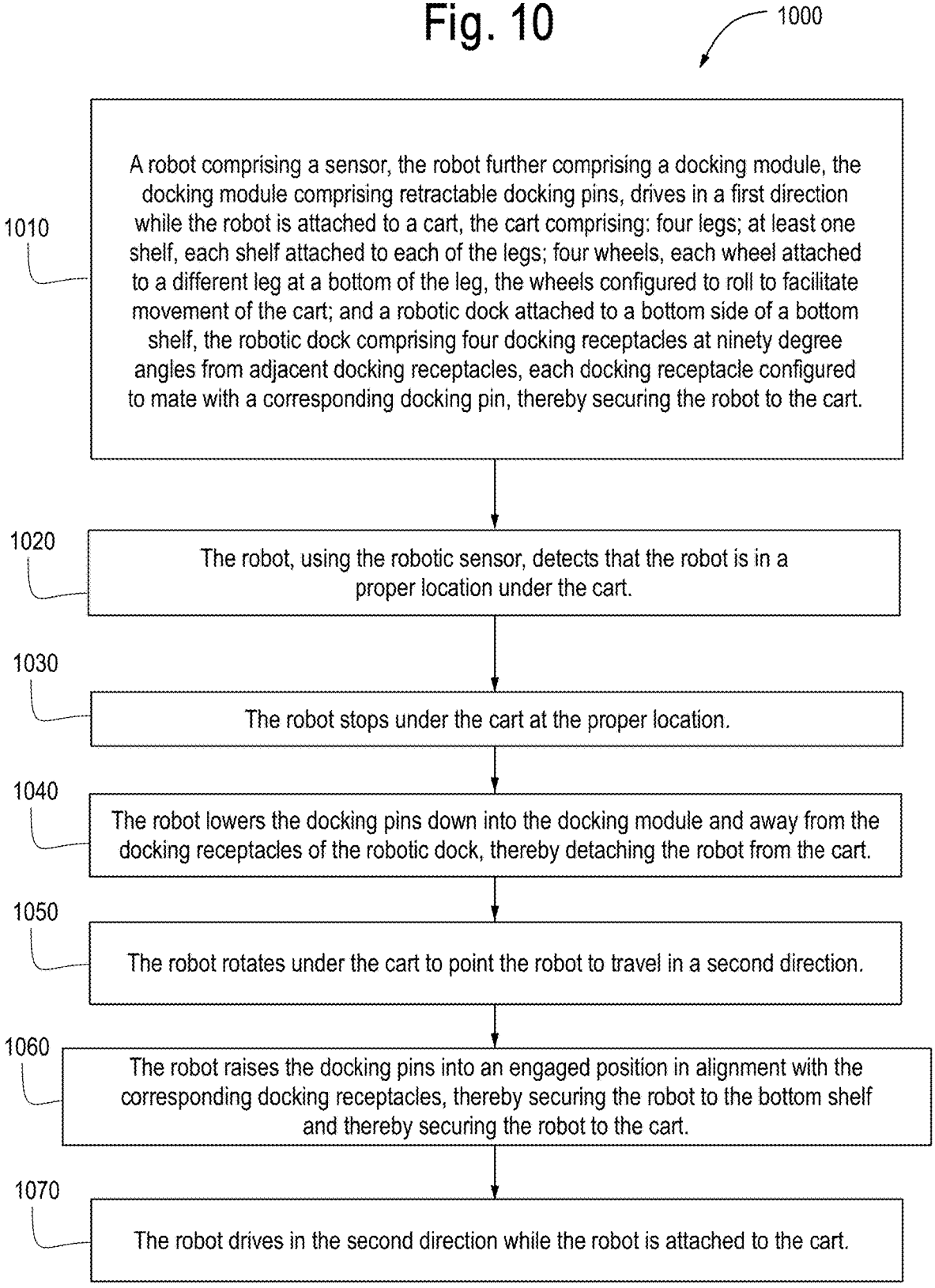
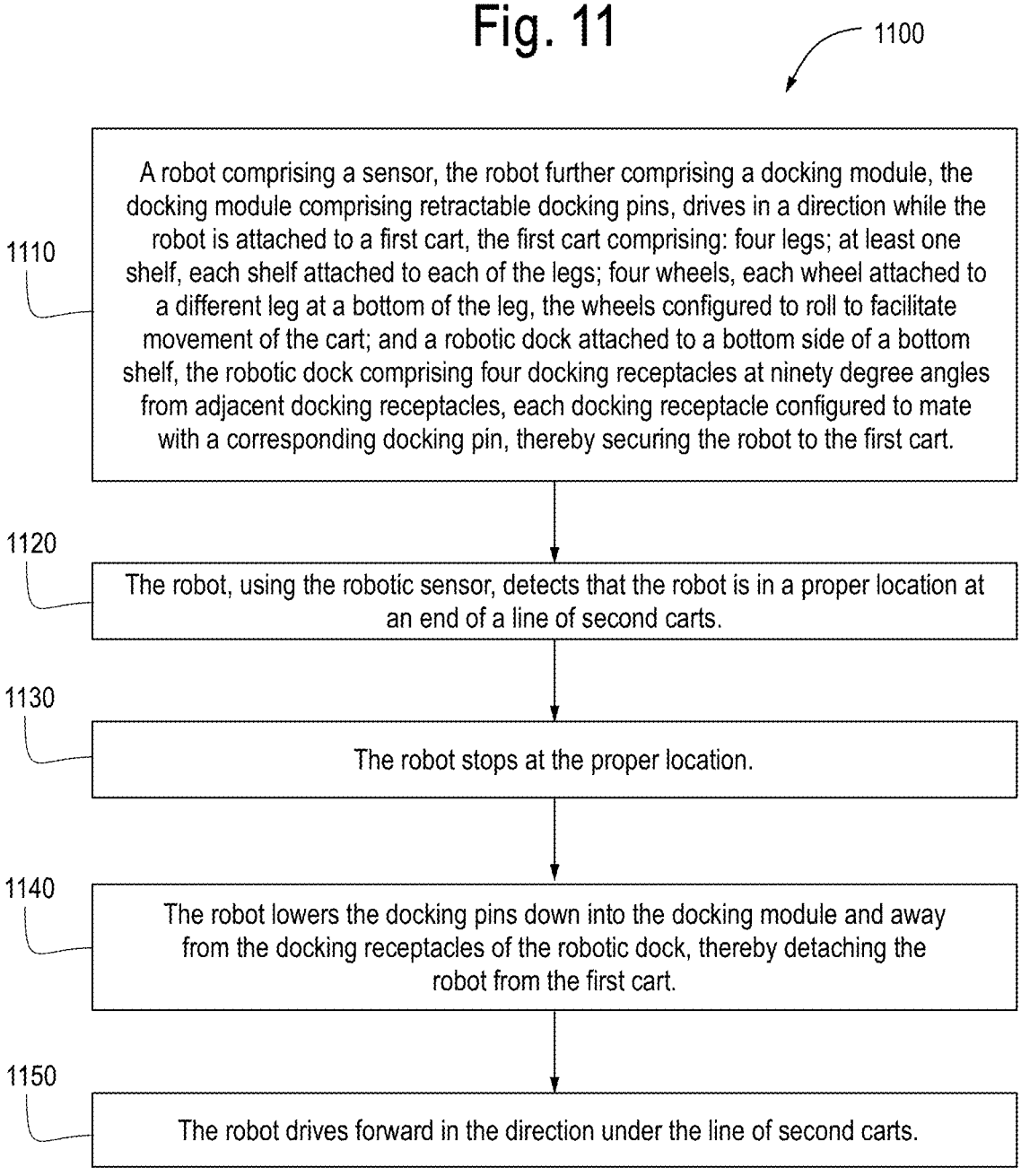

1000
1010
A robot comprising a sensor, the robot further comprising a docking module, the docking module comprising retractable docking pins, drives in a first direction while the robot is attached to a cart, the cart comprising: four legs; at least one shelf, each shelf attached to each of the legs; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, each docking receptacle configured to mate with a corresponding docking pin, thereby securing the robot to the cart.
1020
The robot, using the robotic sensor, detects that the robot is in a proper location under the cart.
1030
The robot stops under the cart at the proper location.
1040
The robot lowers the docking pins down into the docking module and away from the docking receptacles of the robotic dock, thereby detaching the robot from the cart.
1050
The robot rotates under the cart to point the robot to travel in a second direction.
1060
The robot raises the docking pins into an engaged position in alignment with the corresponding docking receptacles, thereby securing the robot to the bottom shelf and thereby securing the robot to the cart.
1070
The robot drives in the second direction while the robot is attached to the cart.

Fig. 11


1100
1110
A robot comprising a sensor, the robot further comprising a docking module, the docking module comprising retractable docking pins, drives in a direction while the robot is attached to a first cart, the first cart comprising: four legs; at least one shelf, each shelf attached to each of the legs; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, each docking receptacle configured to mate with a corresponding docking pin, thereby securing the robot to the first cart.
1120
The robot, using the robotic sensor, detects that the robot is in a proper location at an end of a line of second carts.
1130
The robot stops at the proper location.
1140
The robot lowers the docking pins down into the docking module and away from the docking receptacles of the robotic dock, thereby detaching the robot from the first cart.
1150
The robot drives forward in the direction under the line of second carts.

ROBOTIC CART CONFIGURED FOR EFFECTIVE NAVIGATION AND MULTI-ORIENTATION DOCKING

PRIORITY CLAIM

[0001] The present application claims the priority benefit of U.S. provisional patent application No. 62/655,744 filed Apr. 10, 2018 and entitled "Graphic User Interface and Software for Robotic Management," and of U.S. provisional patent application No. 62/655,755 filed Apr. 10, 2018 and entitled "System and Method for Automatically Annotating a Map," the disclosures of which are incorporated herein by reference.

CROSS-REFERENCE TO RELATED APPLICATIONS

[0002] This application contains subject matter that is related to the subject matter of the following applications, which are assigned to the same assignee as this application. The below-listed applications are hereby incorporated herein by reference in its entirety:

[0003] "ROBOT MANAGEMENT SYSTEM," by Dymesich, et al., co-filed herewith.

[0004] "SYSTEM AND METHOD FOR AUTOMATICALLY ANNOTATING A MAP," by Avagyan, et al., co-filed herewith.

[0005] "SYSTEM AND METHOD FOR ROBOT-ASSISTED, CART-BASED WORKFLOWS," by Cairl, et al., co-filed herewith.

SUMMARY

[0006] A robotic cart is provided. For example, a cart is configured for one or more of robotic navigation and multi-orientation robotic docking.

[0007] For example, a substantially square robotic cart is provided. For example, a square robotic cart is provided. For example, a square robotic cart is configured for one or more of robotic navigation and multi-orientation robotic docking.

[0008] A system includes: a cart including: four legs; at least one shelf, each shelf attached to each of the legs; the cart having a generally rectangular shape, a width of the cart being longer than a length of the robot, a length of the cart being longer than a length of the robot; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles; and a robot comprising: a sensor; and a docking module, the docking module comprising retractable docking pins, each retractable docking pin configured, when extended upward, to mate with a corresponding docking receptacle, thereby securing the robot to a bottom shelf of the cart.

[0009] A system includes: a cart including: four legs; four substantially square shelves, each shelf attached to each of the legs; the cart having a generally rectangular shape, a width of the cart being longer than a length of the robot, a length of the cart being longer than a length of the robot; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, the bottom shelf having a bottom shelf height greater than a robot height of the robot; and a robot comprising: a sensor; and a docking module, the docking module comprising retractable docking pins, each retractable docking pin configured, when extended upward, to mate with a corresponding docking receptacle, thereby securing the robot to the bottom shelf of the cart, the docking module having a docking module height that is configured to approximately match a robotic dock height of the robotic dock, the robot having a horizontal cross section that is one or more of generally circular and generally square.

[0010] A method for efficient robotic reversal of direction while carrying a cart includes: by a robot including a sensor, the robot further including a docking module, the docking module comprising retractable docking pins, driving in a first direction while the robot is attached to a cart, the cart comprising: four legs; at least one shelf, each shelf attached to each of the legs; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, each docking receptacle configured to mate with a corresponding docking pin, thereby securing the robot to the cart; by the robot, using the robotic sensor, detecting that the robot is in a proper location under the cart; by the robot, stopping under the cart at the proper location; by the robot, lowering the docking pins down into the docking module and away from the docking receptacles of the robotic dock, thereby detaching the robot from the cart by the robot, rotating under the cart to point the robot to travel in a second direction; by the robot, raising the docking pins into an engaged position in alignment with the corresponding docking receptacles, thereby securing the robot to the bottom shelf and thereby securing the robot to the cart; and by the robot, driving in the second direction while the robot is attached to the cart.

[0011] A method for efficient robotic cart transfer includes: by a robot including a sensor, the robot further including a docking module, the docking module comprising retractable docking pins, driving in a direction while the robot is attached to a first cart, the first cart comprising: four legs; at least one shelf, each shelf attached to each of the legs; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of the bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, each docking receptacle configured to mate with a corresponding docking pin, thereby securing the robot to the first cart; detecting, by the robot, using the robotic sensor, that the robot is in a proper location at an end of a line of second carts; stopping, by the robot, at the proper location; lowering the docking pins down into the docking module and away from the docking receptacles of the robotic dock, thereby detaching the robot from the first cart; and driving forward, by the robot in the direction, passing under the line of second carts.

DESCRIPTION OF THE DRAWINGS

[0012] The accompanying drawings provide visual representations which will be used to more fully describe various representative embodiments and can be used by those skilled in the art to better understand the representative embodi-

ments disclosed herein and their inherent advantages. In these drawings, like reference numerals identify corresponding elements.

[0013] FIG. **1** is a side perspective drawing of a square robotic cart.

[0014] FIG. **2** is a drawing providing a bottom view of the robotic cart.

[0015] FIG. **3** is a side perspective drawing of a scene in which a robot docks with the cart.

[0016] FIGS. **4**A-**4**C are a series of drawings showing the robot attaching to the cart using the docking module on a bottom side of a bottom shelf.

[0017] FIGS. **5**A-**5**D are a set of drawings showing the robot docking with the cart in each of four different orientations of the robot respective to the cart.

[0018] FIGS. **6**A-**6**E are a series of drawings showing how the robot can navigate while moving the cart by detaching from and then reattaching to the cart.

[0019] FIGS. **7**A-**7**F are a series of drawings showing how the robot can negotiate a 90-degree turn while moving the cart by detaching from the cart, turning 90 degrees, and reattaching to the cart.

[0020] FIGS. **8**A-**8**F are a series of drawings showing how the robot can safely navigate away from an obstacle while moving the cart by detaching from and then reattaching to the cart.

[0021] FIGS. **9**A-**9**G are a series of drawings showing an example of efficient robotic cart transfer in which the robot drives under a line of carts.

[0022] FIG. **10** is a flow chart of a method for efficient robotic reversal of direction while carrying a cart.

[0023] FIG. **11** is a flow chart of a method for efficient robotic cart transfer.

DETAILED DESCRIPTION

[0024] FIG. **1** is a side perspective drawing of a robotic cart **100**. Optionally, and as depicted, but not necessarily, the cart **100** is substantially square. For example, the cart **100** has sides **105** having a length of approximately two feet. For example, the cart **100** has sides **105** having a length of approximately one meter. In order to fit under the cart **100**, a robot (not shown in this figure) docking with the cart **100** has one or more of a width and a length smaller than the first distance **125**A. Preferably, the robot has both a width smaller than the first distance **125**A and a length smaller than the first distance **125**A. In order to fit under the cart **100**, the robot (not shown in this figure) docking with the cart **100** has one or more of a width and a length smaller than the second distance **125**B. Preferably, the robot has both a width smaller than the second distance **125**B and a length smaller than the second distance **125**B.

[0025] The robotic cart **100** comprises at least one shelf **110**A-**110**D for use in holding a payload (not shown) transported on the cart **100**. As depicted, but not necessarily, the cart **100** comprises four shelves **110**A-**110**D. Preferably, though not necessarily, at least one of the shelves **110**A-**110**D is substantially square. For example, though not necessarily, the shelves **110**A-**110**D are all substantially square. The shelves **110**A-**110**D comprise a surface configured to do one or more of supporting and containing the payload. Alternatively, or additionally, the shelves comprise a container configured to do one or more of support and containing the payload. As depicted, the shelves **110**A-**110**D comprise substantially flat shelves. For example, at least one of the shelves **110**A-**110**D has a lip around the edge to prevent the payload from slipping off the cart **100** during motion. As depicted, each of the shelves **110**A-**110**D has a lip around the edge to prevent the payload from slipping off the cart **100** during motion. The shelves **110**A-**110**D can be attached to the cart **100**. For example, the shelves **110**A-**110**D can be permanently attached to the cart **100**. For example, the shelves **110**A-**110**D can be one or more of glued, stapled, bolted and nailed to the cart **100**. Alternatively, or additionally, the shelves **110**A-**110**D can be removably attached to the cart **100**.

[0026] The robotic cart **100** further comprises a plurality of legs **120**A-**120**D. As depicted, the robotic cart **100** comprises four legs **120**A-**120**D. The legs **120**A-**120**D of the cart **100** can be attached to the shelves **110**A-**110**D. For example, the legs **120**A-**120**D of the cart **100** can be permanently attached to the shelves **110**A-**110**D. Alternatively, or additionally, the legs **120**A-**120**D can be removably attached to at least one of the shelves **110**A-**110**D. Alternatively, or additionally, the legs **120**A-**120**D can be attached to the cart **100**. For example, the legs **120**A-**120**D can be permanently attached to the cart **100**. For example, the legs **120**A-**120**D can be one or more of glued, stapled, bolted and nailed to the cart **100**. Alternatively, or additionally, the legs **120**A-**120**D can be removably attached to the cart **100**. A first distance **125**A runs from the first leg **120**A to the second leg **120**B. Similarly a second distance **125**B runs from the second leg **120**B to the third leg **120**C. Again, a third distance **125**C runs from the third leg **120**A to the fourth leg **120**D. Again, a fourth distance **125**D runs from the fourth leg **120**D to the first leg **120**A.

[0027] In order to fit around the robot (not shown in this figure), a cart **100** docking with the robot has a first distance **125**A larger than one or more of a width of the robot and a length of the robot. Preferably, the cart **100** docking with the robot has a first distance **125**A larger than both the width of the robot and the length of the robot. In order to fit around the robot (not shown in this figure), a cart **100** docking with the robot has a second distance **125**B larger than one or more of the width of the robot and the length of the robot. Preferably, the cart **100** docking with the robot has a second distance **1258** larger than both the width of the robot and the length of the robot.

[0028] At least one of the legs **120**A-**120**D comprises a wheel **130**A-**130**D. The first leg **120**A comprises the first wheel **130**A, and so on. The wheels **130**A-**130**D can be attached to the cart **100**. For example, the wheels **130**A-**130**D can be permanently attached to the cart **100**. For example, the wheels **130**A-**130**D can be one or more of glued, stapled, bolted and nailed to the cart **100**. Alternatively, or additionally, the wheels **130**A-**130**D can be removably attached to the cart **100**.

[0029] As depicted, all four of the legs **120**A-**120**D comprise a corresponding wheel **130**A-**130**D. As depicted, the wheels **130**A-**130**D are located at a bottom of the respective legs **120**A-**120**D. As depicted, the wheels **130**A-**130**D are configured to roll to facilitate movement of the cart **100**.

[0030] Alternatively or additionally, the legs **120**A-**120**D can be attached to a frame (not pictured) from which the shelves **110**A-**110**D can be removed. For example, at least one shelf **110**A-**110**D can comprise one or more of a tote and a bin. In this case, a human worker can load the cart **100** as usual. Alternatively, or additionally, the human can detach the tote from the cart **100** and load the tote before putting the

tote back on the cart **100**. Alternatively, or additionally, the human can pick the tote from one or more of a facility, a shelf, a conveyor, and the like. The human can then load the tote onto the cart **100**. Then the human can request the robot to pick up the cart **100** as usual. According to this set of embodiments, the robotic dock need not be attached to a shelf **110**A-**110**D.

[0031] The bottom shelf **110**D further comprises a robotic dock **140**. Alternatively, or additionally, the cart **100** comprises the robotic dock **140**. The robotic dock **140** has a robotic dock height **145**. For example, the robotic dock height **145** is configured to approximately match a docking module height of a docking module of the robot (not shown in FIG. **1**).

[0032] For example, the robotic dock **140** can be permanently attached to the bottom shelf **110**D. For example, the robotic dock **140** can be permanently attached to a bottom side of the bottom shelf **110**D. For example, the robotic dock **140** can be one or more of glued, stapled, bolted and nailed to the bottom shelf **110**D. Alternatively, or additionally, the robotic dock **140** can be removably attached to the bottom shelf **110**D. For example, the bottom shelf **110**D has a height greater than a height of the robot (not shown in this figure). In the case of the set of embodiments in which at least one of the shelves **110**A-**110**D comprises one or more of a tote and a bin, the robotic dock is attached to the one or more of a tote and a bin.

[0033] The robotic dock **140** comprises a plurality of docking receptacles **150**A-**150**D. As depicted, the robotic dock **140** comprises four docking receptacles **150**A-**150**D. As depicted in more detail in FIG. **4**B, the robotic dock **140** is configured to dock with a robot (not shown in this figure) using one or more of the docking receptacles **150**A-**150**D.

[0034] Optionally, the robotic cart **100** further comprises one or more bands **160**A-**160**D. As depicted, the robotic cart **100** comprises four legs **120**A-**120**D. The bands **160**A-**160**D can be attached to the corresponding legs **120**A-**120**D. For example, the bands **160**A-**160**D can be permanently attached to the corresponding legs **120**A-**120**D. For example, the bands **160**A-**160**D can be one or more of glued, stapled, bolted and nailed to the corresponding legs **120**A-**120**D. Alternatively, or additionally, the bands **160**A-**160**D can be removably attached to the corresponding legs **120**A-**120**D.

[0035] A leg **120**A-**120**D, for example, the first leg **120**A, can be distinguished from the other legs **120**B-**120**D using the first band **160**A. For example, the first leg **120**A can be marked with a first band **160**A having a different property from the bands **160**B-**160**D on the other legs **120**B-**120**D. For example, the first leg **120**A may comprise a band **160**A having a different infrared (IR) signal from the other bands **160**B-**160**D on the other legs **120**B-**120**D. For example, the robot's sensor (not shown in this figure) can detect the different IR signal. For example, the bands **160**A-**160**D allow a user to distinguish a preferred orientation for the robot to attach to or drop off the cart **100**.

[0036] FIG. **2** is a drawing providing a bottom view **200** of the robotic cart **100**. The robotic cart **100** again comprises the bottom shelf **110**D (the only shelf visible in the bottom view **200**), the legs **120**A-**120**D, the wheels **130**A-**130**D, the robotic dock **140**, the docking receptacles **150**A-**150**D, and the optional bands **160**A-**160**D. Also shown again are the first through fourth distances **125**A-**125**D. To attach to a cart **100**, the robot **310** drives to a location in a vicinity of the cart **100**, approximately facing a space between two cart legs as shown in FIG. **3**.

[0037] For example, the robot **310** is symmetric about a central axis. For example, the robot has a horizontal cross section that is one or more of generally circular and generally square.

[0038] FIG. **3** is a side perspective drawing of a scene **300** in which a robot **310** docks with the cart **100**. The robotic cart **100** again comprises the shelves **110**A-**110**D, the legs **120**A-**120**D, the wheels **130**A-**130**D, the robotic dock **140** having the robotic dock height **145**, the docking receptacles **150**A-**150**D, and the bands **160**A-**160**D. Also shown again are the first through fourth distances **125**A-**125**D. The robot **310** comprises a sensor **315**. For example, the robotic sensor **315** can detect an orientation of the cart **100**. For example, the robotic sensor **315** can detect an orientation of the cart **100** for purposes of arranging one or more of a pickup of the cart **100** by the robot **310** and a dropoff of the cart **100** by the robot **310**. For example, as discussed above with reference to FIG. **1**, the robotic sensor **315** can detect the orientation of the cart **100** using a band **160**A having a different IR band from that of the other bands **160**B-**160**D. For example, the robot comprises retractable docking pins **350**A, **350**B.

[0039] For example, the sensor **315** comprises one or more of a laser scanner and a three-dimensional (3D) camera. For example, the 3D camera comprises one or more of a stereo camera and a time-of-flight camera. Using the sensor **315**, the robot **310** obtains data about the position of the cart **100** relative to the robot **310**. Using the sensor **315**, the robot **310** detects one or more of the legs **120**A-**120**D of the cart **100**.

[0040] The robot **310** then uses the detected position of the one or more legs **120**A-**120**D to do one or more of drive itself to the cart **100**, position itself under the cart **100**, and align one or more of the docking pins **350**A, **350**B of the robot **310** with corresponding docking receptacles **150**A-**150**D thereby securing the robot **310** to the bottom shelf **110**D and thereby securing the robot **310** to the cart **100**.

[0041] The robot **310** faces an opening **125**A between two legs **120**A and **120**B of the cart **100** before driving in a direction indicated by arrow **330** under the cart **100** to connect to the cart **100**. Also shown are the shelves on the cart **110**A-**110**D, other two legs **120**C and **10**D, and the wheels **130**A-**130**D. Because of a symmetrical design of one or more of the cart **100** and the robot **310**, the robot **310** can connect to the cart **100** by facing, and then entering, the opening between any two adjacent legs **120**A-**120**D.

[0042] The robot **310** further comprises a docking module **340**. For example, the robotic dock height **145** is configured to approximately match a docking module height **345** of the docking module **340**. The docking module **340** comprises docking pins **350**A and **350**B. The docking pins **350**A and **350**B are configured to align with corresponding docking receptacles **150**A-**150**D, thereby securing the robot **310** to the bottom shelf **110**D and thereby securing the robot **310** to the cart **100**.

[0043] FIGS. **4**A-**4**C are a series of drawings showing the robot **310** attaching to the cart **100** using the docking module **340** on the bottom side of the bottom shelf **110**D.

[0044] FIG. **4**A is a perspective drawing **400** that shows the robot **310** attaching to the cart **100** using the docking module **340** on the bottom side of the bottom shelf **110**D. The robotic cart **100** again comprises the shelves **110**A-

110D, the legs 120A-120D, the wheels 130A-130D, the robotic dock 140 having the robotic dock height 145, the docking receptacles 150A-150D, and the bands 160A-160D. Also shown again are the first through fourth distances 125A-125D. The robot 310 again comprises the sensor 315, the docking module 340 having the docking module height 345, and the retractable docking pins 350A and 350B.

[0045] In FIG. 4A, the robot 310 aligns the docking pins 350A and 350B with corresponding docking receptacles 150A and 150B, thereby securing the robot 310 to the bottom shelf 110D and thereby securing the robot 310 to the cart 100.

[0046] FIGS. 4B-4C show detail views of the docking of the robot 310 with the cart 100. For example, the robot 310 docks with the robotic dock 140, thereby attaching the robot 310 to the cart 100, using the two docking pins 350A and 350B that insert into the respective docking receptacles 150A and 150B.

[0047] FIG. 4B shows a disengaged detail view 410 shows the docking pins 350A and 350B are shown in a disengaged position in which they are lowered relative to the robot 310. Also shown are the robotic dock 140 and the docking receptacles 150A and 150B.

[0048] FIG. 4C shows an engaged detail view 420 showing details of the robot 310 after it has docked with the robotic dock 140, inserting the docking pins 350A and 350B into the respective docking receptacles 150A and 150B. In FIG. 4C, the docking pins 350A and 350B are in an engaged position in which they are raised relative to the robot 310.

[0049] When the sensor 315 on the robot 310 detects that the robot 310 is in a proper location under the cart 100, the robot 310 raises its docking pins 350A and 350B up from the docking module 340 into an engaged position in alignment with the respective docking receptacles 150A and 150B. The robot 310 thereby secures itself to the bottom shelf 110D and thereby secures itself to the cart 100. After docking, the robot 310 attaches to the cart 100. When the robot 310 drives, the cart 100 moves with the robot 310.

[0050] FIGS. 5A-5D are a set 500 of four drawings showing the robot 310 docking with the cart 100 in each of four different orientations of the robot 310 respective to the cart 100. The robotic cart 100 again comprises the shelves 110A-110D, the legs 120A-120D, the wheels 130A-130D, and the robotic dock 140 having the robotic dock height 145. Also shown again are the first through fourth distances 125A-125D. Not visible in these figures are the optional bands. The robot 310 again comprises the sensor 315, the docking module 340 having the docking module height 345, and the retractable docking pins 350A and 350B.

[0051] Because of the respective shapes of the docking module 340 and the docking pins 350A and 350B on the robot 310, the robot 310 can dock with the cart 100 in any of four orientations as shown in FIGS. 5A-5D. For example, the robot 310 can dock with the cart 100 in a tight space in any of the four orientations shown in FIGS. 5A-5D. A tight space is defined as a space having a dimension (not shown in this figure; shown in FIGS. 6A-6E, 7A-7F, and 9A-9G) less than approximately 1.5 times a length 105 of a cart side. For example, if the length of the cart side 105 is approximately 2 feet, a space is defined as tight if, as shown the dimension (not shown in this figure; shown in FIGS. 6A-6E, 7A-7F, and 9A-9G) is less than approximately 3 feet.

[0052] When the sensor 315 on the robot 310 detects that the robot 310 is in a proper location under the cart 100, the robot 310 raises its docking pins 350A and 350B up from the docking module 340 into an engaged position in alignment with the docking receptacles (not shown in this drawing). In FIGS. 5A-5D, the cart 100 stays in the same orientation and the robot 310 is shown connecting to the cart 100 in each of four orthogonal configurations.

[0053] FIGS. 6A-6E are a series 600 of five drawings showing how the robot 310 can navigate while moving the cart 100 by detaching from and then reattaching to the cart 100. For example, the robot 310 can navigate out of a tight space such as a hallway 610 while moving the cart 100 by detaching from and then reattaching to the cart 100. One or more of the cart 100 and the robot 310 are configured so that the robot 310 can disengage from the cart 100, turn, and then re-engage with the cart 100. That is, the robot 310 can turn without having to rotate the cart 100 in order to point its sensor in a new direction of travel. The robot again comprises the sensor (not shown in these figures), the docking module 340, and the retractable docking pins 350A and 350B.

[0054] The cart 100 comprises sides 105. A tight space is defined as a space having a dimension 615 less than approximately 1.5 times a length 105 of a cart side. For example, if the length of the cart side 105 is approximately 2 feet, a space is defined as tight if, as shown the dimension 615 is less than approximately 3 feet.

[0055] In FIG. 6A, while attached to the cart 100, the robot 310 drives to the end of the hallway 610. The hallway 610 is bounded by a hallway wall 620. Also shown are the legs 120A-120D. The arrow 630 does not represent a physical feature but indicates a current direction of travel of the robot 310 to the right, toward the end of the hallway 610.

[0056] In FIG. 6B, when the sensor (not shown in this figure) on the robot 310 detects that the robot 310 is in a proper location under the cart 100, the robot 310 lowers the docking pins 350A and 350B down into the docking module 340 and away from the docking receptacles (not shown in this figure) of the robotic dock (not shown in this figure). The robot 310 thereby detaches from the cart (not shown in this figure).

[0057] In FIG. 6C, the robot 310, now detached from the cart 100, rotates counterclockwise 180 degrees under the cart 100. The arrow 630 indicates a point near completion of a counterclockwise 180 degree rotation of the current direction of travel of the robot 310.

[0058] Shown again are the legs 120A-120D, the hallway 610, and the hallway wall 620. The positions of the cart legs 120A-120D remain the same as the robot 310 turns as the robot 310 is detached from the cart 100.

[0059] In FIG. 6D, when the sensor (not shown in this figure) on the robot 310 detects that the robot 310 is in a proper location under the cart 100, the robot 310 raises the docking pins 350A and 350B up from the docking module 340 toward the cart 100 and into alignment with the docking receptacles (not shown in this figure). The robot 310 thereby reattaches to the cart (not shown in this figure).

[0060] Because of the shape of the docking module 340 on the cart 100, the robot 310 is able to insert the docking pins 350A and 350B into receptacles (not shown in this figure) 180 degrees away from the receptacles with which the docking pins 350A and 350B were previously docked. The robot 310 is thus able to dock with the cart 100 in a position at a 180 degree angle to its previous docked position shown in FIG. 7C.

[0061] In FIG. **6**E, the robot **310**, now attached again to the cart **100**, drives in a direction **640** straight out of the hallway **610** bounded by the hallway wall **620**. The arrow **630** again does not represent a physical feature but indicates a current direction of travel of the robot **310** to the left, away from the end of the hallway **610**. Shown again are the legs **120**A-**120**D.

[0062] The design of the robot **310** and the cart **100** allow the robot **310** with the cart **100** attached to navigate efficiently out of a tight space. For safety reasons, the robot **310** may need to turn around to point its sensor (not shown in this figure) in the direction **630** of its travel. However, the robot **310** does not need to rotate the whole cart **100** 180 degrees to turn itself around.

[0063] FIGS. **7**A-**7**F are a series **700** of six drawings showing how the robot **310** can make a 90-degree turn **710** while moving the cart **100** by detaching from the cart **100**, turning 90 degrees, and reattaching to the cart **100**. One or more of the cart **100** and the robot **310** are configured so that the robot **310** can disengage from the cart **100**, turn, and then re-engage with the cart **100**. That is, the robot **310** can make the 90-degree turn **710** without having to rotate the cart **100** in order to point its sensor in a new direction of travel. For example, the 90-degree turn **710** comprises a tight 90-degree turn. The robot **310** again comprises the docking module (not shown in this figure; item **340** in FIGS. **7**C and **7**E). The robot **310** again comprises the retractable docking pins (not shown in this figure; items **350**A and **350**B in FIGS. **7**C and **7**E).

[0064] A tight turn **710** is defined as a turn having a dimension **715** less than approximately 1.5 times a length **105** of a cart side. For example, if the length of the cart side **105** is approximately 2 feet, a space is defined as tight if, as shown the dimension **715** is less than approximately 3 feet.

[0065] In FIG. **7**A, while attached to the cart **100**, the robot **310** approaches the 90-degree turn **710**. Also shown are the legs **120**A-**120**D. The arrow **630** again does not represent a physical feature but indicates a current direction of travel of the robot **310** to the right, toward the 90-degree turn **710**.

[0066] In FIG. **7**B, while attached to the cart **100**, the robot **310** reaches the point **710** at which it needs to turn. The arrow **630** indicates a current direction of travel of the robot **310** to the right, toward the 90-degree turn **710** at which the robot **310** has just arrived. Also shown again are the legs **120**A-**120**D.

[0067] In FIG. **7**C, when the sensor (not shown in this figure) on the robot **310** detects that the robot **310** is in a proper location under the cart **100**, the robot **310** lowers the retractable docking pins **350**A and **350**B down into the docking module **340** and away from the docking receptacles (not shown in this figure) of the robotic dock (not shown in this figure). The robot **310** thereby detaches from the cart (not shown in this figure).

[0068] In FIG. **7**D, the robot **310**, now detached from the cart **100**, rotates clockwise 90 degrees under the cart **100**. Following completion of the 90 degree rotation, the robot **310** drives in a direction **720**. The arrow **630** indicates a current direction of travel of the robot **310** to the bottom of the page, away from the 90 degree turn **710**, although the robot **310** has not yet re-attached to the cart **100** so the robot **310** is not yet ready to move in the direction indicated by the arrow **630**. Shown again are the legs **120**A-**120**D. The positions of the cart legs **120**A-**120**D remain the same as the robot **310** turns as the robot **310** is detached from the cart **100**.

[0069] In FIG. **7**E, when the sensor (not shown in this figure) on the robot **310** detects that the robot **310** is in a proper location under the cart **100**, the robot **310** raises its docking pins **350**A and **350**B up from the docking module **340** toward the cart (not shown in this figure) and into alignment with the docking receptacles (not shown in this figure). The robot **310** thereby reattaches to the cart (not shown in this figure).

[0070] Because of the shape of the docking module **340** on the cart **100**, the robot **310** is able to insert the docking pins **350**A and **350**B into receptacles (not shown in this figure) 90 degrees away from the receptacles with which the docking pins **350**A and **350**B were previously docked. The robot **310** is thus able to dock with the cart **100** in a position at an approximate 90 degree angle to its previous docked position shown in FIG. **7**C.

[0071] In FIG. **7**F, the robot **310**, now attached again to the cart **100**, drives in the direction **720** straight out away from the point **710**. The arrow **630** indicates the current direction of travel of the robot **310** to the bottom of the page, away from the 90 degree turn **710**. Shown again are the legs **120**A-**120**D.

[0072] The design of the robot **310** and the cart **100** again allow the robot **310** with the cart **100** attached to navigate efficiently out of tight spaces. For safety reasons, the robot **310** may need to turn around to point its sensor (not shown in this figure) in the direction **720** of its travel.

[0073] Again the robot **310** does not need to rotate the whole cart **100** 90 degrees to turn itself around.

[0074] FIGS. **8**A-**8**F are a series **800** of six drawings showing how the robot **310** can safely navigate away from another obstacle, for example, a forklift **810**, while moving the cart **100** by detaching from and then reattaching to the cart **100**. One or more of the cart **100** and the robot **310** are configured so that the robot **310** can disengage from the cart **100**, turn, and then re-engage with the cart **100**. That is, the robot **310** can turn without having to rotate the cart **100** in order to point its sensor in a new direction of travel. The robot **310** again comprises the docking module **340**. The robot **310** again comprises the retractable docking pins **350**A and **350**B.

[0075] In FIG. **8**A, while attached to the cart **100**, the robot **310** drives in a current direction of travel represented by the arrow **630**. A forklift **810** suddenly appears directly ahead of the robot as an unexpected obstacle. Also shown are the legs **120**A-**120**D. The forklift is moving in a forklift direction **812**. The forklift **810** comes to a stop very close to the cart **100**, at a distance **815** from the cart. For example, the distance **815** comprises a tight distance. A tight distance **815** is defined as a distance less than approximately 1.5 times a length **105** of a cart side. For example, if the length of the cart side **105** is approximately 2 feet, a distance is defined as tight if, as shown the dimension **815** is less than approximately 3 feet.

[0076] The tight distance **815** means that the robot **310** would not be able to turn around while carrying the cart **100**.

[0077] In FIG. **8**B, the robot **310** comes to a stop near the forklift **810**. Alternatively, or additionally, the forklift **810** comes to a stop near the robot **310**. The robot **310** is so close to the forklift **810** that the robot **310** cannot turn in place without the cart **100** colliding with the forklift **810**.

[0078] As shown in FIG. **8**C, when the sensor (not shown in this figure) on the robot **310** detects that the robot **310** is in a proper location under the cart **100**, the robot **310** lowers the docking pins **350**A and **350**B down into the docking module **340** and away from the docking receptacles (not shown in this figure) of the robotic dock (not shown in this figure). The robot **310** thereby detaches from the cart (not shown in this figure).

[0079] In FIG. **8**D, the robot **310**, now detached from the cart **100**, rotates counterclockwise 180 degrees under the cart **100**. The arrow **630** indicates a counterclockwise 180 degree rotation of the current direction of travel of the robot **310**.

[0080] Shown again are the legs **120**A-**120**D and the forklift **810**. The positions of the cart legs **120**A-**120**D remain the same as the robot **310** turns as the robot **310** is detached from the cart **100**.

[0081] In FIG. **8**E, when the sensor (not shown in this figure) on the robot **310** detects that the robot **310** is in a proper location under the cart **100**, the robot **310** raises the docking pins **350**A and **350**B up from the docking module **340** toward the cart (not shown in this figure) and toward the docking receptacles (not shown in this figure). The robot **310** thereby reattaches to the cart (not shown in this figure).

[0082] Because of the shape of the docking module **340** on the cart **100**, the robot **310** is able to insert the docking pins **350**A and **350**B into receptacles (not shown in this figure) 180 degrees away from the receptacles with which the docking pins **350**A and **350**B were previously docked. The robot **310** is thus able to dock with the cart **100** in a position at a 180 degree angle to its previous docked position shown in FIG. **8**C.

[0083] In FIG. **8**F, the robot **310**, now attached again to the cart **100**, drives in a direction **840** away from the forklift **810**. The arrow **630** again does not represent a physical feature but indicates a current direction of travel of the robot **310** to the left, away from the forklift **810**. Shown again are the legs **120**A-**120**D.

[0084] The design of the robot **310** and the cart **100** allow the robot **310** with the cart **100** attached to navigate efficiently out of tight spaces. For safety reasons, the robot **310** may need to turn around to point its sensor (not shown in this figure) in the direction **630** of its travel. However, the robot **310** does not need to rotate the whole cart **100** 180 degrees to turn itself around.

[0085] Robots are also able to drive under a line of carts, enabling an efficient workflow involving a cart dropoff or a cart pickup.

[0086] FIGS. **9**A-**9**G are a series **900** of seven drawings showing an example of a robot driving under a line of carts **100**A-**100**C. One or more of the cart **100** and a first robot **310**A are configured so that the first robot **310**A disengages from a cart **100**D that it is carrying and then travels under a line of carts **100**A-**100**C. The first robot **310**A again comprises a first docking module **340**A. The first robot **310**A again comprises retractable docking pins **350**A, **350**B (visible in FIGS. **9**E and **9**G).

[0087] For example, the series of events shown in FIGS. **9**A-**9**G may occur in a setting involving a tight space. The cart **100** comprises sides **105**. A tight space is defined as a space having a dimension **905** less than approximately 1.5 times a length **105** of a cart side. In this case, the dimension **905** comprises a clearance between a first obstacle **907** and a second obstacle **908**. For example, if the length of the cart side **105** is approximately 2 feet, a space is defined as tight if, as shown, as shown, the dimension **905** is less than approximately 3 feet.

[0088] FIG. **9**A shows a line of carts **100**A-**100**C that have already been dropped off by one or more of humans and robots.

[0089] In FIG. **9**B, a first robot **310**A that is attached to a fourth cart **100**D is driving toward the line of carts **100**A-**100**C to drop off the fourth cart **100**D. The first robot **310**A drives in a direction **910**. An arrow **630**A indicates a current direction of travel of the first robot **310**A.

[0090] In FIG. **9**C, the first robot **310**A, while still attached to the fourth cart **100**D, arrives at the end of the line of carts **100**A-**100**C. The first robot **310**A detaches from the fourth cart **100**D. To detach from the fourth cart **100**D, the first robot **310**A follows a similar process to that shown above in FIGS. **6**B, **7**C, and **8**C. That is, when the sensor (not shown in this figure) on the first robot **310**A detects that the first robot **310**A is in a proper location under the fourth cart **100**D, the first robot **310**A lowers the docking pins (not shown in this figure; visible as items **350**A and **350**B in FIGS. **9**E and **9**G) down into the first docking module (not shown in this figure; visible as item **340**A in FIGS. **9**E and **9**G) and away from the docking receptacles (not shown in this figure) of the robotic dock (not shown in this figure). The first robot **310**A thereby detaches from the fourth cart **100**D.

[0091] In FIG. **9**D, the first robot **310**A, now detached from the fourth cart **100**D, drives straight under carts **100**A-**100**C in a direction **920**. The arrow **630**A indicates the current direction of travel of the first robot **310**A, to the left toward the cart **100**A at the end of the carts **100**A-**100**D.

[0092] A second robot **3106** that is attached to a fifth cart **100**E is driving toward the line of carts **100**A-**100**D to drop off the fifth cart **100**E. The second robot **310**B drives in a direction **930**. An arrow **630**B indicates a current direction of travel of the second robot **310**B. The second robot **310**B comprises a second docking module **340**B. The second robot **310**B again comprises retractable docking pins **350**C and **350**D.

[0093] FIG. **9**E shows a side view of FIG. **9**D where the first robot **310**A is starting to drive under the carts **100**A-**100**C after dropping off its fourth cart **100**D at the end of the line of carts **100**A-**100**D. The fourth cart **100**D has a first robotic dock **140**A having a first robotic dock height **145**A. The fifth cart **100**E has a second robotic dock **140**B having a second robotic dock height **145**B.

[0094] The first robot **310**A comprises a first docking module **340**A having a first docking module height **345**A. As the first robot **310**A drives under the carts, the second robot **310**B approaches to drop off its cart **100**E behind the cart **100**D that is dropped off by the first robot **310**A.

[0095] The second robot **310**B comprises a second docking module **340**B having a second docking module height **345**B. The second robot **310**B detaches from the fifth cart **100**E. To detach from the fifth cart **100**E, the second robot **310**B follows a similar process to that shown above in FIGS. **6**B, **7**C, **8**C, and **9**C. That is, when the sensor (not shown in this figure) on the second robot **310**B detects that the second robot **310**B is in a proper location under the fifth cart **100**E, the second robot **310**B lowers the docking pins **350**C and **350**D down into the second docking module **340**B and away from the docking receptacles (not shown in this figure) of the

robotic dock (not shown in this figure). The second robot **310**B thereby detaches from the fifth cart **100**E.

[0096] In FIG. **9**F, the first robot **310**A passes under the third cart **100**C and continues to drive straight under the carts **100**A-**100**C in the direction **920**. The arrow **630**A indicates the current direction of travel of the first robot **310**A, to the left toward the cart **100**A at the end of the carts **100**A-**100**E.

[0097] The second robot **310**B, now detached from the fifth cart **100**E, stops. The arrow **630**B indicates the current direction of travel of the second robot **310**B, to the left toward the cart **100**A at the end of the carts **100**A-**100**E.

[0098] FIG. **9**G shows a side view of FIG. **9**F where the first robot **310**A is continuing to drive under the carts **100**A-**100**C and the second robot has stopped after dropping off its cart **100**E at the end of the line of carts **100**A-**100**D.

[0099] FIG. **10** is a flow chart of a method **1000** for efficient robotic cart transfer.

[0100] The order of the steps in the method **1000** is not constrained to that shown in FIG. **10** or described in the following discussion. Several of the steps could occur in a different order without affecting the final result.

[0101] In step **1010**, a robot comprising a sensor, the robot further comprising a docking module, the docking module comprising retractable docking pins, drives in a first direction while the robot is attached to a cart, the cart comprising: four legs; at least one shelf, each shelf attached to each of the legs; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, each docking receptacle configured to mate with a corresponding docking pin, thereby securing the robot to the cart. For example, the step of driving in the first direction comprises driving to the end of a space. Block **1010** then transfers control to block **1020**.

[0102] In step **1020**, the robot, using the robotic sensor, detects that the robot is in a proper location under the cart. Block **1020** then transfers control to block **1030**.

[0103] In step **1030**, the robot stops under the cart at the proper location. Block **1030** then transfers control to block **1040**.

[0104] In step **1040**, the robot lowers the docking pins down into the docking module and away from the docking receptacles of the robotic dock, thereby detaching the robot from the cart. Block **1040** then transfers control to block **1050**.

[0105] In step **1050**, the robot rotates under the cart to point the robot to travel in a second direction. For example, the second direction comprising an approximate reverse of the first direction. Block **1050** then transfers control to block **1060**.

[0106] In step **1060**, the robot raises the docking pins into an engaged position in alignment with the corresponding docking receptacles, thereby securing the robot to the bottom shelf and thereby securing the robot to the cart. Block **1060** then transfers control to block **1070**.

[0107] In step **1070**, the robot drives in the second direction while the robot is attached to the cart. Block **1070** then terminates the process.

[0108] FIG. **11** is a flow chart of a method **1100** for efficient robotic cart transfer.

[0109] The order of the steps in the method **1100** is not constrained to that shown in FIG. **11** or described in the following discussion. Several of the steps could occur in a different order without affecting the final result.

[0110] In step **1110**, a robot comprising a sensor, the robot further comprising a docking module, the docking module comprising retractable docking pins, drives in a direction while the robot is attached to a first cart, the first cart comprising: four legs; at least one shelf, each shelf attached to each of the legs; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, each docking receptacle configured to mate with a corresponding docking pin, thereby securing the robot to the first cart. Block **1110** then transfers control to block **1120**.

[0111] In step **1120**, the robot, using the robotic sensor, detects that the robot is in a proper location at an end of a line of second carts. Block **1120** then transfers control to block **1130**.

[0112] In step **1130**, the robot stops at the proper location. Block **1130** then transfers control to block **1140**.

[0113] In step **1140**, the robot lowers the docking pins down into the docking module and away from the docking receptacles of the robotic dock, thereby detaching the robot from the first cart. Block **1140** then transfers control to block **1150**.

[0114] In step **1150**, the robot drives forward in the direction under the line of second carts. Block **1150** then terminates the process.

[0115] An advantage of the invention is that the design of one or more of the cart and the robot allows the robot to connect to the cart by facing and entering an opening between any two adjacent legs.

[0116] An advantage of the invention is that the flexibility of the robot's ability to dock with the cart as illustrated in FIGS. **5**A-**5**D permits workers to place the cart in a variety of orientations for robotic pickup, rather than spending time making sure the cart is in one specific orientation.

[0117] A still further advantage of embodiments of the invention is that one or more of the cart and the robot are configured to navigate efficiently out of tight space. A still further advantage of embodiments of the invention is that one or more of the cart and the robot are configured so that the robot can disengage from the cart, turn, and then re-engage with the cart. That is, the robot can turn without having to rotate the cart in order to point its sensor in a new direction of travel.

[0118] An additional advantage is that the design of one or more of the cart and the robot allows the robot to turn around without having to rotate the cart.

[0119] An advantage of the invention is that the distinguishing bands on the cart legs allow a user to designate a preferred orientation for the robot to attach to or drop off the cart.

[0120] A still further advantage of embodiments of the invention is that a robot can drive under a line of carts and thereby improve efficiency.

[0121] Another advantage of embodiments of the invention is that the ability of the robots to drive under the carts means that the robots do not need to change their trajectories to avoid each other. This has the additional advantages of

keeping the flow of robot traffic to a single direction and keeping the area around the carts more clear as the robot traffic is funneled under the carts. Yet another advantage is that areas adjacent to the line of carts can be high traffic areas for humans, forklifts, and the like and robots will be able to travel in their own protected space under the carts without interfering with traffic.

[0122] It will be understood by those skilled in the art that software used by the method for automatic annotation of a map may be located in any location in which it may be accessed by the system. It will be further understood by those of skill in the art that the number of variations of the network, the location of the software, and the like are virtually limitless.

[0123] For example, the robot can, instead of rotating counterclockwise under the cart as discussed in FIGS. **6-9**, instead rotate clockwise under the cart. For example, the robot could comprise docking receptacles and the cart could comprise retractable docking pins without substantially affecting the functioning of the invention.

[0124] While the above representative embodiments have been described with certain components in exemplary configurations, it will be understood by one of ordinary skill in the art that other representative embodiments can be implemented using different configurations and/or different components. For example, it will be understood by one of ordinary skill in the art that the order of certain steps and certain components can be altered without substantially impairing the functioning of the invention.

[0125] The representative embodiments and disclosed subject matter, which have been described in detail herein, have been presented by way of example and illustration and not by way of limitation. It will be understood by those skilled in the art that various changes may be made in the form and details of the described embodiments resulting in equivalent embodiments that remain within the scope of the invention. It is intended, therefore, that the subject matter in the above description shall be interpreted as illustrative and shall not be interpreted in a limiting sense.

What is claimed is:

1. A system comprising:

a cart comprising:

four legs;

at least one shelf, each shelf attached to each of the legs;

the cart having a generally rectangular shape, a width of the cart being longer than a length of the robot, a length of the cart being longer than a length of the robot;

four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and

a robotic dock, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles; and

a robot comprising:

a sensor; and

a docking module, the docking module comprising retractable docking pins, each retractable docking pin configured, when extended upward, to mate with a corresponding docking receptacle, thereby securing the robot to a bottom shelf of the cart.

2. The system of claim **1**, wherein the robotic dock has a robotic dock height that is configured to approximately match a docking module height of the docking module.

3. The system of claim **1**, wherein at least one shelf is removably attached to at least one leg.

4. The system of claim **1**, the cart comprising four shelves.

5. The system of claim **1**, wherein the robot is symmetric about a central axis.

6. The system of claim **5**, wherein the robot has a horizontal cross section that is one or more of generally circular and generally square.

7. The system of claim **1**, wherein the cart comprises at least one substantially square shelf.

8. The system of claim **4**, wherein the cart comprises four substantially square shelves.

9. The system of claim **1**, wherein the robotic dock is attached to the bottom shelf.

10. The system of claim **9**, wherein the robotic dock is attached to a bottom side of a bottom shelf.

11. The system of claim **1**, wherein the bottom shelf has a height greater than a height of the robot.

12. The system of claim **1**, at least one leg of the cart further comprising a band.

13. The system of claim **12**, wherein the band is configured to distinguish the leg from at least one of the other legs.

14. The system of claim **13**, wherein the band has a different property from at least one other band.

15. The system of claim **14**, wherein the different property comprises a different band signal.

16. The system of claim **15**, wherein the different band signal comprises a different infrared (IR) signal.

17. The system of claim **16**, wherein the IR signal is detectable by the robotic sensor.

18. The system of claim **17**, wherein the band is usable to detect an orientation of the cart.

19. The system of claim **1**, wherein the robotic sensor comprises an infrared (IR) sensor.

20. The system of claim **1**, wherein the robot connects to the cart by entering an opening between any two adjacent legs.

21. The system of claim **1**, wherein the robot connects to the cart in each of four orthogonal configurations.

23. The system of claim **1**, wherein the robot connects to the cart in each of four orthogonal configurations with the cart in a same position.

24. The system of claim **1**, wherein the robot while carrying the cart is configured to change direction in a tight space, wherein a tight space is defined as a space having a dimension less than approximately 1.5 times a length of the cart side.

25. The system of claim **1**, wherein one or more of the robot and the cart is configured to efficiently transfer the cart in a tight space, wherein a tight space is defined as a space having a dimension less than approximately 1.5 times a length of the cart side.

26. The system of claim **1**, wherein one or more of the robot and the cart is configured so that the robot can turn around without having to rotate the cart.

27. The system of claim **1**, wherein the distinguishing band on the cart leg allows a user to designate a preferred orientation for the robot to attach to or drop off the cart.

28. The system of claim **1**, wherein the robot can disengage from the cart, turn, and then re-engage with the cart.

29. A system comprising:

a cart comprising:

four legs;

four substantially square shelves, each shelf attached to each of the legs;

the cart having a generally rectangular shape, a width of the cart being longer than a length of the robot, a length of the cart being longer than a length of the robot;

four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and

a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, the bottom shelf having a bottom shelf height greater than a robot height of the robot; and

a robot comprising:

a sensor; and

a docking module, the docking module comprising retractable docking pins, each retractable docking pin configured, when extended upward, to mate with a corresponding docking receptacle, thereby securing the robot to the bottom shelf of the cart, the docking module having a docking module height that is configured to approximately match a robotic dock height of the robotic dock, the robot having a horizontal cross section that is one or more of generally circular and generally square.

30. A method for efficient robotic reversal of direction while carrying a cart, comprising:

by a robot comprising a sensor, the robot further comprising a docking module, the docking module comprising retractable docking pins, driving in a first direction while the robot is attached to a cart, the cart comprising: four legs; at least one shelf, each shelf attached to each of the legs; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, each docking receptacle configured to mate with a corresponding docking pin, thereby securing the robot to the cart;

by the robot, using the robotic sensor, detecting that the robot is in a proper location under the cart;

by the robot, stopping under the cart at the proper location;

by the robot, lowering the docking pins down into the docking module and away from the docking receptacles of the robotic dock, thereby detaching the robot from the cart;

by the robot, rotating under the cart to point the robot to travel in a second direction;

by the robot, raising the docking pins into an engaged position in alignment with the corresponding docking receptacles, thereby securing the robot to the bottom shelf and thereby securing the robot to the cart; and

by the robot, driving in the second direction while the robot is attached to the cart.

31. The method of claim 30, the second direction comprising an approximate reverse of the first direction.

32. The method of claim 30, the second direction comprising a direction at an approximately 90 degree angle to the first direction.

33. The method of claim 30, wherein the step of driving in the first direction comprises driving to the end of a space.

34. The method of claim 30, wherein the step of driving in the first direction comprises driving to the end of a tight space, wherein a tight space is defined as a space having a dimension less than approximately 1.5 times a length of the cart side.

35. The method of claim 30, wherein the step of driving in the second direction comprises driving out of a tight space, wherein a tight space is defined as a space having a dimension less than approximately 1.5 times a length of the cart side.

36. The method of claim 30, wherein the robot is symmetric about a central axis.

37. The method of claim 30, wherein the robot has a horizontal cross section that is one or more of generally circular and generally square.

38. The method of claim 30, wherein the cart comprises at least one substantially square shelf.

39. The method of claim 30, wherein the cart comprises four substantially square shelves.

40. The method of claim 30, wherein the robotic dock is attached to a bottom shelf.

41. The method of claim 30, wherein the robotic dock is attached to a bottom side of a bottom shelf.

42. The method of claim 1, wherein the robot while carrying the cart is configured to change direction in a tight space, wherein a tight space is defined as a space having a dimension less than approximately 1.5 times a length of the cart side.

43. The method of claim 1, wherein one or more of the robot and the cart is configured to efficiently transfer the cart in a tight space, wherein a tight space is defined as a space having a dimension less than approximately 1.5 times a length of the cart side.

44. The method of claim 1, wherein one or more of the robot and the cart is configured so that the robot can turn around without having to rotate the cart.

45. The system of claim 1, wherein the robot can disengage from the cart, turn, and then re-engage with the cart.

46. A method for efficient robotic cart transfer, comprising:

by a robot comprising a sensor, the robot further comprising a docking module, the docking module comprising retractable docking pins, driving in a direction while the robot is attached to a first cart, the first cart comprising: four legs; at least one shelf, each shelf attached to each of the legs; four wheels, each wheel attached to a different leg at a bottom of the leg, the wheels configured to roll to facilitate movement of the cart; and a robotic dock attached to a bottom side of a bottom shelf, the robotic dock comprising four docking receptacles at ninety degree angles from adjacent docking receptacles, each docking receptacle configured to mate with a corresponding docking pin, thereby securing the robot to the first cart;

detecting, by the robot, using the robotic sensor, that the robot is in a proper location at an end of a line of second carts;

stopping, by the robot, at the proper location;

lowering the docking pins down into the docking module and away from the docking receptacles of the robotic dock, thereby detaching the robot from the first cart; and

driving forward, by the robot in the direction, passing under the line of second carts.

47. The method of claim **46**, wherein the robot is symmetric about a central axis.

48. The method of claim **46**, wherein the robot has a horizontal cross section that is one or more of generally circular and generally square.

49. The method of claim **46**, wherein the cart comprises at least one substantially square shelf.

50. The method of claim **46**, wherein the cart comprises four substantially square shelves.

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